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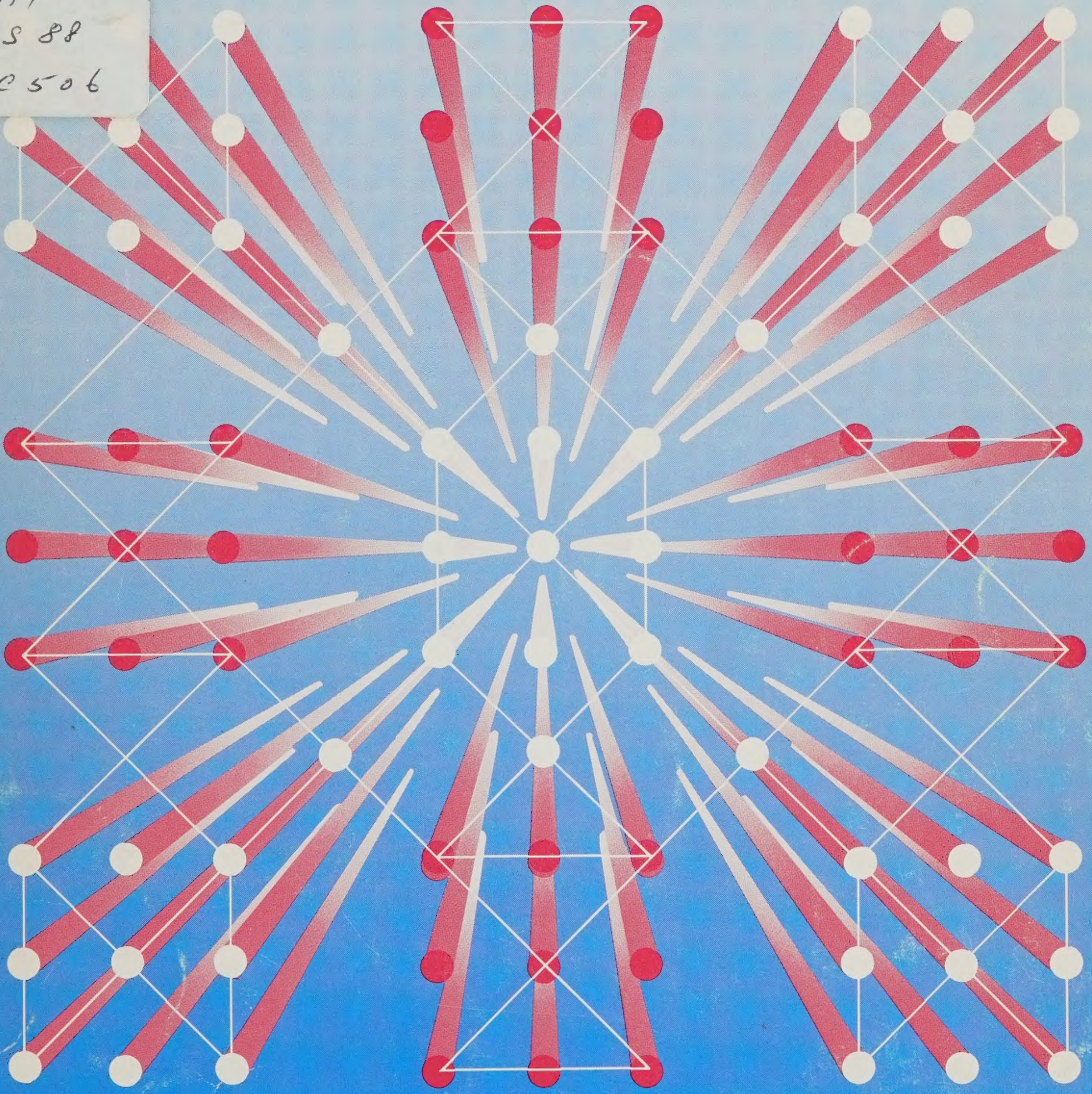

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A Framework for Measuring Research and Development Expenditures in Canada

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PREFACE

This report describes the concepts, definitions and methodology underlying the collection of statistics on research and development expenditures in Canada. It is based on the guidelines published by the Organisation for Economic Co-operation and Development and describes the adaptation of these to the Canadian situation. It also notes some of the problems of data collection and of the analysis of the published statistics.

Science and technology indicators may be defined as statistics which measure quantifiable aspects of the creation, dissemination and application of science and technology. As indicators, they should help to describe the science and technology system, enabling better understanding of its structure, of the impact of policies and programs on it, and of the impact of science and technology on society and the economy.

A Framework for Measuring Research and Development Expenditures in Canada is one of a series of background papers on science and technology indicators to be published by Statistics Canada. The purpose of the series is to describe the theoretical development, limitations and application of various statistics suggested as indicators of science and technology.

Current indicators of Canada's scientific and technological activities include:

- expenditures on research and development;
- federal government scientific activities;
- personnel working in science and technology;
- Canadian research output (citations);
- Canadian patented inventions;
- international payments and receipts for technology;
- trade in selected commodities.

Statistical tabulations of the indicators will be released in **Canadian Science Indicators,** Catalogue 88-201, an annual summary; **Industrial Research and Development Statistics,** Catalogue 88-202 (annual); **Resources for Research and Development in Canada,** Catalogue 88-203 (annual); **Federal Science Activities,** Catalogue 88-204 (annual); and in a monthly service bulletin, **Science Statistics,** Catalogue 88-001.

A list of the proposed background papers is included at the end of this publication. These papers represent the opinions of the authors and do not necessarily represent those of Statistics Canada. Comments are invited and should be addressed to Karen Walker of the Science and Technology Statistics Division.

This review of a framework for measuring research and development in Canada was written by Mr. Alan Sunter, formerly of Statistics Canada, and now a consultant in Ottawa.

Martin B. Wilk
Chief Statistician of Canada

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Chapter 1

SCIENCE AND TECHNOLOGY: AN R&D PERSPECTIVE

Introduction

In general discussion, scientific research and experimental development (R&D) are often considered synonymous with science and technology. Thus the first step in describing the framework for measuring R&D is to distinguish it from the larger field of scientific and technological activities (S&T). There are three logical steps to this:

- describe the broad concept of scientific and technological activities (see Scientific and Technological Activities);
- provide a definition of R&D within the broader framework of scientific and technological activities (see Research and Development Defined);
- provide guidance where the R&D boundary is ambiguous (see Definitional Problems).

These three steps employ the guidelines/standard classifications for measuring S&T activity and, in particular R&D expenditures, established by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Organisation for Economic Co-operation and Development (OECD). (A brief account of the relevant activities of these two international organizations is provided in Appendix I.)

Scientific and Technological Activities

Although the concept of S&T activities is the same for both UNESCO and the OECD, the two international organizations differ somewhat in their classifications of the components of S&T activities because the OECD considers S&T activities only as they relate to R&D.

UNESCO defines scientific and technological activities as:

"...systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technical knowledge in all fields of science and technology. These include such activities as R&D, scientific and technical education and training (STET) and the scientific and technological services (STS)...".(1)

(1) **Recommendation Concerning the International Standardization of Statistics on Science and Technology,** UNESCO, 1978, Annex 1.

UNESCO therefore includes R&D as one of a number of activities within the category of scientific and technological activities. The other activities are STET and STS.

STET covers: "...all activities comprising specialized non-university higher education and training, higher education and training leading to a university degree, post-graduate and further training, and organized lifelong training for scientists and engineers".(2)

This activity includes post-graduate studies in which a marked degree of R&D is often performed by students. Under this definition the resources devoted to R&D are therefore, not included in university R&D expenditures.

The STS are defined as "...activities concerned with research and experimental development and contributing to the generation, dissemination and application of scientific and technical knowledge".(3) For the purposes of surveying and measuring S&T activity, these activities are divided into nine sub-classes:

- S&T activities of libraries, etc.;
- S&T activities of museums, etc.;
- translation, editing, etc., of S&T literature;
- surveying (geological, hydrological, etc.);
- prospecting;
- data collection on socio-economic phenomena;
- testing, standardization and quality control, etc.;
- client counselling including public agricultural and industrial advisory services, etc.; and
- patent and licence activities by public bodies.

The STS does not separate R&D from these "related" S&T activities; for example, there could be some R&D included in the S&T activities of libraries and museums.

In comparison, the OECD now collects data only on R&D; other S&T activities are identified only to facilitate the definition of R&D. It divides S&T activities into four main components: R&D, education and training, other related S&T activities and other industrial

(2) **Ibid.**
(3) **Ibid.**

activities. Generally, the second and third components correspond respectively to the UNESCO activities of STET and STS.

Education and training are defined in the Frascati Manual as "All education and training of personnel in the natural sciences, engineering, medicine, agriculture, the social sciences and the humanities in universities and special institutions of higher and post-secondary education".(4) Unlike the UNESCO definition, research conducted by post-graduate students is not included in this activity component.

Other related S&T activities are divided into seven sub-classes similar to the UNESCO divisions:

- S&T information services;
- general purpose data collection;
- testing and standardization;
- feasibility studies;
- specialized medical care;
- patent and licence work;
- policy related studies.

The fourth component in the OECD concept of S&T activity, other industrial activities, corresponds to the non-R&D activities which may be involved in innovation. The activity or process of innovation consists of all the scientific, technical, commercial and financial steps necessary for the successful development and marketing of an idea into:

- a new or improved saleable product;
- an operational process in industry and commerce; or
- a new approach to a social service.

These non-R&D activities have been classified as:

- patent work;
- financial and organizational changes required for an innovation;
- new product marketing;
- final product or design engineering;
- tooling and industrial engineering;
- manufacturing start-up.

Generally speaking then, scientific and technological activities, as defined by UNESCO and the OECD, can be classified into four general components:

- research and experimental development,
- education and training,
- other related S&T activities,
- other industrial activities.

(4) **The Measurement of Scientific and Technical Activities - Proposed Standard Practice for Surveys of Research and Experimental Development,** OECD, Paris, 1981, p. 26.

By defining the latter three categories, it is easier to establish R&D as a distinct component of the broader S&T activity. Resources devoted to these three activities are excluded from the measurement of R&D expenditures.

Research and Development Defined

Both the OECD and UNESCO define R&D as: "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications".(5)

Defining each of the components of S&T activity presents problems. Education and training, other related S&T activities, and other industrial activities may all contain an element of R&D which should be properly included in R&D expenditures. The basic criterion for distinguishing R&D from the rest of S&T activity is that there be an "appreciable element of novelty".

Definitional Problems

Education and Training

Distinguishing R&D from a wide range of related activities with a scientific and technological base is difficult because often these related activities can be very closely linked to R&D through information flows and in terms of the operation, institution and personnel. In particular, within universities, research and teaching are often inextricably linked since most academic staff perform both functions. Similarly, many buildings and much equipment, serve both purposes. Because of this close connection between R&D and instruction, the measurement of the proportion of sources exclusive to R&D is generally based on an estimate of working time devoted to this activity by university staff.

Post-graduate studies also present definitional problems. Parts of the curricula for post-graduate studies are highly structured, involving compulsory courses, laboratory work, etc. In addition to this mandatory study, however, the students are often required to perform independent research. This activity fulfills the criterion of novelty and, therefore should be included in estimates of university R&D expenditures. (Note the cost would also include supervision by the respective teachers.)

Other Related S&T Activities

Difficulties in separating R&D within this class of S&T activities arise because many

(5) **Ibid.**, p. 25.

different activities with a scientific and technological base may be performed at the same institution.

For example, the staff of laboratories whose main purpose is to perform testing and quality control may also devote time to devising new and substantially improved methods of testing. The latter activity is considered R&D while the former is not. However, in the financial statements of such institutions the two classes of expenditure may not be distinguished. The converse may also occur: in some institutions the primary purpose is to perform R&D while other related S&T activities (such as testing) are secondary activities. Again, these classes of expenditure may not be distinguished.

Guidelines for identifying these different activities are:

- Insofar as a secondary activity is undertaken primarily in the interests of R&D, it should be included in R&D expenditures; if the secondary activity is designed essentially to meet needs other than R&D, it should be excluded from R&D.

- Institutions whose main purpose is an R&D related scientific activity often undertake some research in connection with this activity. Such research should be isolated and included when measuring R&D.

Other applications for these guidelines occur in the activities of S&T information services. In the case of a research laboratory library which is maintained principally for the use of the research workers of the laboratory, the activities should be included in R&D. If, however, the activities of a firm's documentation centre are open to all staff they should be excluded from R&D expenditures. Similarly, the activities of central university libraries should be excluded from R&D.

Other Industrial Activities

Possibly the greatest source of error in measuring R&D expenditures is in determining the cut-off point between experimental development and related activities required during the realization of an innovation. This situation is most prevalent when measuring industrial R&D. While many innovations require costly R&D, the expenses of preparing the innovation for production are often higher still. Examples of these costly activities include design engineering, tooling and manufacturing start-up.

A basic guideline, as proposed by the National Science Foundation of the United States and quoted in the Frascati Manual, is:

"If the primary objective is to make further technical improvements on the product or process, then the work comes within the definition of R&D. If, on the other hand, the product, process or approach is substantially set and the primary objective is to develop markets, to do pre-production planning or to get a production or control system working smoothly, then the work is no longer R&D".(6)

Pilot plants illustrate the application of this guideline. The construction and operation of a plant is a part of R&D as long as the principal purposes are to obtain experience and to compile engineering and other data to be used in evaluating hypotheses, designing special equipment and structures required by a new process, and preparing operating instructions or manuals on the process.

As soon as this experimental phase is over, and the pilot plant becomes a normal commercial production unit, the activity can no longer be considered R&D. It makes no difference if, while in the R&D stage, the plant's output happens to be sold. The distinction rests on whether the primary objective of the activity is to obtain experience and new information, which is R&D, or if the direct objective is to make money, which is not R&D.

The same guideline applies for a prototype; i.e., an original model on which something new is patterned and which possesses the basic characteristics of the intended product. The boundary of R&D has been reached when any necessary modifications to the prototype(s) have been made and the testing is satisfactorily completed. The construction of several copies of a prototype to meet a temporary commercial, military or medical need after successful testing of the original, even if done by R&D staff, is not part of R&D.

(6) **Ibid.**, p. 34.

Chapter 2

MEASURING RESEARCH AND DEVELOPMENT

Introduction

The standard measure or indicator of a country's R&D effort is the summary statistic, gross domestic expenditures on R&D or GERD. The term, defined to facilitate international comparison of R&D activities, refers to total expenditures on R&D within a country.

Several steps are involved in constructing this statistic. They are:

- identifying and defining the resources to be measured (see R&D Expenditures Defined);
- defining procedures for measuring resources (see Flow of Funds);
- defining the statistic, its uses and limitations (see GERD).

Within the following discussions, the term "statistical unit" is used frequently and refers to the various organizational levels for which R&D activity can be reported. The different levels can refer to a country, a sector of the economy, a sub-sector, or an institution.

The smallest unit, i.e., the institution, represents a business enterprise, a government department or agency, an institute for higher education, etc. Data for all businesses can be aggregated to represent the Business enterprise sector, provincial and federal government departments data can be combined to represent the Government sector, etc. Finally, all defined sectors are aggregated to represent a country's activity.

R&D Expenditures Defined

R&D resources can be measured in two ways: as financial expenditures, and as personnel engaged in R&D.(7) Both are expressed over a specified period, usually 12 months, both are collected from the smallest unit for which information is available and then aggregated into larger or higher level units for analysis purposes and then finally, totalled to provide an R&D perspective at the national level.

A chief disadvantage of measuring R&D in monetary terms is that it is affected by differences in price levels and currency values over time and between countries. However, although the measurement of R&D input by personnel is not affected directly by these differences, it is faced with the problem of reducing the data to a standardized person-year basis. For instance, a normal working day may differ from sector to sector and from country to country. As well, "It is generally easier to get satisfactory data on R&D expenditures than on personnel engaged in R&D, mainly because of more extensive financial accounts. The estimates (of total R&D personnel) should therefore be used with some caution. This is regretable, since suitable personnel are the foundation of R&D and such personnel cannot be procured or allocated as easily as dollars."(8)

There are two types of financial expenditures on R&D; intramural expenditures and extramural expenditures.

Intramural expenditures are defined as all expenditures for R&D performed within a statistical unit, regardless of the source of the funds. They include both current and capital expenditures.

Current expenditures are composed of: labour costs of R&D personnel (e.g., salaries, fringe benefits, appropriate share of grants of post-graduate students performing R&D); purchase of materials, supplies, and minor equipment to support R&D (e.g., fuel, chemicals, books); and purchase of services (e.g., hired security, repair and maintenance, computer services) or lease of facilities to support R&D.

Capital expenditures are the annual gross expenditures on fixed assets used in the R&D programme of a statistical unit. They are composed of expenditures on land and buildings, instruments and equipment. All depreciation provisions for buildings, plant and equipment, should be excluded from the measurement of intramural expenditures.

Extramural expenditures are funds expended by one statistical unit for R&D which was performed by another unit. An example of this would be a government department funding an R&D project that was performed by a private organization. Inside the national territory, extramural expenditures by one sector are identified in the intramural expenditures of another

(7) For a brief account of personnel resources as a measure of R&D, see Appendix II.

(8) **Annual Review of Science Statistics, 1982,** Statistics Canada, Catalogue 13-212, Ottawa, 1982, p. 31.

sector which performed the R&D. Payments made by a sector to an organization outside the country, however, are not covered in national total intramural expenditures. Extramural expenditures are supplementary to the basic measure of intramural expenditures.

Flow of Funds

Procedures for measuring R&D expenditures, as listed in the Frascati Manual, are:

- identify the intramural expenditure on R&D performed by each statistical unit;
- identify the sources of funds for these intramural R&D expenditures as reported by the performer;
- identify the extramural R&D expenditures of each statistical unit; and
- aggregate the data, by sector of performance and source of funds, to derive national totals.

Essentially, these aggregations and separations establish measurements of the flow of R&D expenditures from one unit to another (or sector or country). One of the main areas of interest in examining R&D activity is this transfer of resources, since it is important for national science policy makers to know who is funding R&D and who is performing it.

The OECD stresses that the reporting of R&D expenditures should be by the performer, as opposed to the funder. Thus, the strongly recommended method of measuring transfers is performer-based reporting of the sums which one unit, organization or sector has received from another unit, organization or sector for the performance of intramural R&D. To examine the flow of funds between the units GERD is often displayed in matrix form (Table A).

TABLE A. Gross Domestic Expenditures on R&D (GERD)

Funding sector(1)	Performing sector				Total
	Business enterprise	Private non-profit	Government	Higher education	
Business enterprise					Total financed by the Business enterprise sector
Private non-profit					Total financed by the Private non-profit sector
Government					Total financed by the Government sector
Public GUF(2)					Total financed by Public GUF
Higher education					Total financed by the Higher education sector
Abroad					Total financed from Abroad
Total	Total performed in the Business enterprise sector	Total performed in the Private non-profit sector	Total performed in the Government sector	Total performed in the Higher education sector	GERD

(1) As reported by performing sector.
(2) Refers to government financed general university funds assumed to be required to cover R&D costs. GUF is declared separately so that it can be reclassified or excluded when necessary.

The criteria for identifying the flows of R&D funds are two-fold:

- there must be a direct transfer of resources;
- this transfer must be both intended and used for the performance of R&D.

Direct transfers may take the form of contracts, grants or donations and involve money or other resources (such as equipment lent to the performer). When there is a significant non-monetary transfer, the current value should be estimated since all transfers must be expressed in financial terms.

Criterion two above may be taken for granted. There are, however, situations where its application can clarify, for example, a discrepancy between the reported R&D expenditures of the performer and of the funder. The following example from the Frascati Manual illustrates this point:

"...when a unit gives funds to another in return for equipment or services needed for its own R&D. If the provision of this equipment or these services does not require the second unit to carry out R&D, it cannot report performing R&D funded by the first unit. For example, suppose a government laboratory buys standard equipment or uses an outside computer to perform calculations required for an R&D project. The equipment supplier or the computer service firm carry out no R&D themselves and would report no R&D funded by the government. These expenditures should be considered by the government laboratory, for R&D statistics, to be **intramural capital** and **intramural other current** costs respectively."(9)

Similarly, discrepancies can occur when there are transfers of funds which are loosely described by the source as "development contracts" for "prototypes" which actually result in no R&D being performed by the funder and very little by the recipient. The converse is also possible, i.e., discrepancies in reported R&D expenditures may occur when one unit receives money from another and uses it for R&D although the funds were not paid out for that purpose.

One specific area of concern in identifying R&D expenditures occurs when determining what proportion of government financed "general university funds" (GUF) is used for R&D. Basically universities receive three types of funding for R&D activities:

"R&D contracts and earmarked grants received from government and other outside sources. These should be credited to their original source.

(9) **Frascati Manual,** op. cit., p. 77.

"Income from endowments, shareholdings, property plus receipts from the sale of non-R&D services such as fees from individual students, subscriptions to journals, sales of serum or agricultural produce. These retained receipts are clearly the universities' 'Own Funds'. In the case of private universities these may be a major source of funds for R&D.

"The general grant they receive from the Ministry of Education or from the corresponding provincial or local authorities in support of their overall research/teaching activities. In this case there is a conflict between the principle of tracing the original source and that of using the performer's report and also some disagreement...".(10)

No standard procedure has been recommended for dealing with general grants since granting mechanisms, attitudes and government/university relations differ among the OECD member countries. The procedure employed as well as the amounts of GUF involved should be classified and documented in order that modifications, if necessary, can be made for international comparisons.

GERD

Definition

Gross domestic expenditures on research and development (GERD) is a statistical series, constructed by adding together the intramural expenditures on R&D as reported by the performing sectors. As a term used by OECD Member countries, it is defined as "total intramural expenditure on R&D performed on the national territory during a given period. It includes R&D performed within a country and funded from abroad but excludes payments made abroad for R&D".(11)

It is often displayed as a matrix of performing and funding sectors (see Flow of Funds). The GERD and GERD matrix are fundamental to internal examination and international comparisons of R&D expenditures.

The matrix illustrates three aspects of a country's R&D effort:

- it shows how much R&D each sector performed over a 12-month period;
- it shows the amount of R&D each sector financed over a 12-month period;
- it indicates the flow of funds between sectors.

(10) **Ibid.,** p. 79.
(11) **Ibid.,** p. 80.

The GERD is an indicator of S&T activities; it is appropriately used as a summary of R&D activities and the basic flow of funds. General guidelines to follow when using a summary statistical series such as the GERD, include:

- Such series provide only a summary of very complex patterns of activities and instructions. The series should, therefore, by used in conjunction with other relevant information.

- Users generally refer to R&D data with a question in mind: "Is our national university research effort declining?" "Does my firm spend a higher proportion of its funds on R&D than the average for my industry?" etc. It is, therefore, necessary to identify the basic data relevant to each question in order to know which R&D indicator is best suited to answering the question. The user should keep in mind that the data used for the R&D indicator may be accurate enough to answer one question but not another.

Limitations of GERD

It is wise to approach intramural expenditures, as a measure of R&D effort, with some caution; partly because of fluctuating dollar values, but also because of certain inherent characteristics of statistical series.

"The GERD, like any other social or economic statistic, can only be approximately true. Different components are of different accuracy: sector estimates probably vary from +/-5% to +/-15% in accuracy...."(12)

One of the most important problems relating to GERD concerns its definition. There remains some ambiguity in defining precisely what constitutes R&D or, for example, in a continuing project, determining the precise point at which the project passes the boundary of R&D and becomes exploitation of a process or product on which it may be said that the R&D stage has been completed. This ambiguity is perhaps less serious in internal time series, where it may be expected that the year-to-year application of the definitions by the same reporting units are at least consistent, than in international comparisons, where the possibility always exists of serious and persistent differences in the application of definitions.

A second difficulty arises with regards to survey design. The people best qualified to apply the R&D definitions and classifications - scientific and technical personnel engaged in the direct management of S&T activity - rarely participate in the statistical agency's data collection process. Because the data collected are concerned not with scientific and technical content, but financial and labour inputs to achieving this content the questionnaires tend to be addressed to and completed by financial and management staff. This is a fundamental problem of all surveys addressed to large organizations, whether they are public or private.

These two problems account for the limited amount of geographic and scientific detail in the published GERD. The amount of detail presented, for example, in the Canadian GERD as published by Statistics Canada is limited by the nature of the surveys, and the other data collection and analysis instruments, on which the series is based. Nor is it possible to increase the amount of detail because this would require switching to new kinds of data collection instruments in a vastly expanded survey operation.

Another reason for the limited detail about sectors stems from the fact that R&D projects are often a secretive endeavour. Private sector companies usually want to surprise competitors with a new product. Thus the money spent on the R&D for that new project would be reported, but details about the R&D project itself would not. Similarly, a government department such as National Defence might report R&D expenditures but not the nature and detail of the respective R&D projects. At best, the GERD provides broad categories of the nature of the R&D work underway; for example, "Transport equipment", "Agricultural machinery and equipment", "Aircraft", etc.

To summarize, the GERD serves as a general indicator of S&T activity and not as a detailed inventory of R&D projects within an organization, sector, or country. It is an estimate and as such can show trends in R&D expenditures by sector and sub-sector, by region and country, from year to year. In this capacity, the GERD estimates are sufficiently reliable for their main use as an aggregate indicator for science policy.

(12) **Science Statistics,** Statistics Canada, Catalogue 13-003, Vol. 6, No. 10, September 1982.

Chapter 3

R&D PERFORMERS AND FUNDERS CATEGORIZED

Sectoring

Considering that the GERD is the aggregate of the total R&D expenditures of the performing sectors, it is useful now to look at these sectors individually. In this chapter the sectors are reviewed in terms of an international (OECD) framework for measuring R&D expenditures. In Chapter 4 Canada is used as an example, providing both a general description of the survey procedures for R&D expenditures for each sector and statistical examples of each sector's respective R&D effort.

There are five major sectors of R&D performance and funding:

- Business Enterprise;
- Private Non-profit Organizations;
- Government;
- Higher Education;
- Abroad.

The sectors for the GERD, as chosen and defined by the OECD, are based largely on existing United Nations classifications and in particular, the System for National Accounts (SNA). Under the general heading of "Institutional Classifications," the OECD approach focuses on the characteristic properties of the performing and funding institutions. Each statistical unit is classified according to its principal economic activity and, consequently, the whole of the R&D resources of the unit classified are allocated to one sector or subsector.

The Frascati Manual lists a number of reasons for grouping R&D performers and funders into standard sectors of the economy. Among the advantages are:

"Different questionnaires and survey methods can be used for each sector to take into account the different "mixes" of activities, different accounting systems or different response possibilities of the organisations.

"When measuring expenditure, the sectoral approach offers the most reliable way of building up national aggregates.

"Sectoring offers a framework for the analysis of flows of funds between the R&D funding and performing agencies.

"Since each sector has its own characteristics and its own blend of R&D, this classification also throws some light on differences between the level and direction of R&D in different countries."(13)

Another major advantage of sectoring using standard economic classifications is that it allows for comparisons with other economic and social statistics. For example, Business enterprise R&D may be compared to industrial variables such as employment or the industrial domestic product. The latter comparison can be used as a ratio (e.g., BERD/industrial domestic product) to show how much priority the Business enterprise sector gives to R&D.

There are, however, problems with the sectoral approach. "In view of the diverse ways in which most contemporary institutions have developed, the definitions of the sectors... cannot be logically precise because...they are based on a combination of sometimes conflicting criteria such as function, aim, economic behaviour, sources of funds and legal status. Thus, it will not always be clear in which sector a given institute should be classified and an arbitrary decision may have to be made."(14)

A certain institution may lie on the borderline between two sectors or the conceptual distinction may be clear but certain legal or political realities prevent it from being put into practice. The sectoral approach encounters much the same problem in practice as does the measurement of R&D itself. That is, artificial distinctions created to facilitate the collection of data are sometimes difficult, if not impossible, to implement where those distinctions are too far removed from the actual workings of a particular institution.

This has led the OECD to recommend that R&D data be collected in as much detail as possible in order to leave room for rearrangement.

Another difficulty arises when two countries classify institutions with the same or similar functions in different sectors, making international comparisons less reliable. The OECD provides alternate approaches to institutional

(13) **Frascati Manual,** op. cit., p. 39.
(14) **Ibid.,** p. 40.

classifications for problem areas such as the Business enterprise sector. These will be discussed under their respective headings.

Business Enterprise

This sector is composed of: "All firms, organisations and institutions whose primary activity is the production of goods or services for sale to the general public at a price intended approximately to cover at least the cost of production."(15)

For the purposes of measuring R&D expenditures, this sector is based, largely, on the United Nations SNA. It consists of private enterprises, public enterprises and non-profit institutes and associations who either serve, or are controlled by, the former two. The core of this sector is made up of private enterprises, amongst which may be firms whose main activity is R&D (commercial R&D institutes and laboratories).

The OECD divides this category into sub-sectors similar to existing United Nations classifications; the units are classified under major headings of industry groups using the International Standard Industrial Classification (ISIC). To make international comparisons easier, however, the OECD has rearranged the ISIC into the following industry groups and component industries:

Agriculture

Mining

Manufacturing:

Electrical machinery
Electrical equipment and components

Chemicals
Drugs
Petroleum refining

Aerospace

Motor vehicles
Ships
Other transport equipment

Ferrous metals
Non-ferrous metals
Fabricated metal products

Instruments
Office and computing machinery
Machinery

Food, drink and tobacco
Textiles, footwear and leather
Rubber and plastic products
Stone, clay and glass
Paper and printing
Wood, cork and furniture
Other manufacturing

Services:

Utilities
Construction
Transport, storage
Communications
Commercial and engineering services

Other activities.

A difficulty here - common to all business enterprise statistical series - is determining the appropriate level of industrial classification of statistical units. A business enterprise may be comprised of a number of legal entities (companies) each of which is the legal owner of one or more establishments, the establishment being regarded as the unit engaged in a homogeneous industrial activity at a single location.

The "enterprise-type" unit is recommended as the statistical unit for the Business enterprise sector. This focuses on the legal entity which controls the performance of the R&D rather than the smaller units which actually carry out the work. Thus, the principal activity of the unit determines the industrial classification (whether the enterprise should be classified, for example, under the heading of Mining or of Basic Metals).

Non-profit institutes and associations, are classified with the industries by which they are administered or which they serve. For example, a textile research institute is included with firms in the textile industry. If a particular institute cannot be identified with any one industry, it comes under the heading "scientific and engineering services not assigned to another industry". This group is a component of the "Services" group listed above.

Because the nature of the R&D performed by an entity often reflects the type of entity, it is useful to distinguish public enterprises (e.g., enterprises owned or controlled by government but operated in a business mode) from private enterprises. According to SNA, the distinction is on the basis of control. "Because of the many forms in which government may exercise control over enterprises, it is difficult to describe the means of influencing the management of an enterprise which, in all cases, indicate who effectively controls a given enterprise. The important consideration in determining whether the public authorities are in control is: do they exercise an effective influence in all the main aspects of management; not merely such influence as is derived from the use of their regulatory powers of a general kind."(16)

(15) **Ibid.**, p. 40.

(16) **Ibid.**, p. 45.

Enterprises within the business sector can also be classified by size measured in terms of number of employees. The following size groups are determined by the total number of employees in the enterprise and refer to all employees, not just those engaged in R&D.

For larger economies	For smaller economies
Under 1,000 employees	Under 100 employees
1,000- 1,999	100- 499
2,000- 4,999	500- 999
5,000- 9,999	1,000-1,999
10,000-24,999	2,000-4,999
25,000 and above	5,000 and above

The OECD recommends that these size groups be confined to statistical units in the manufacturing industries because the ratio of R&D inputs to size is not comparable between non-commercial institutions (e.g., non-profit institutes and associations) whose primary activity is R&D and manufacturing industries where R&D is normally an auxiliary activity.

Private Non-profit Organizations

This sector comprises "private or semi-public organisations which are not established primarily with the aim of making a profit".(17)

This sector consists of voluntary associations (scientific and professional societies, health-oriented groups), philanthropic foundations and research institutes supported by the associations and foundations. These kinds of institutions are usually maintained by fees, dues and donations from members and sponsors and by grants from governments and enterprises. They may also obtain revenue from the sale of their products such as publications or special studies.

The Private non-profit (PNP) sector also includes individual inventors working on their own time and with their own facilities. In principal, private individuals also enter as funders of R&D mainly through donations to PNP. To the extent that this source of funds is reflected in the statistical series (i.e., GERD), it is classified as PNP.

Non-profit institutes and organizations excluded from this sector are those which are controlled by enterprises, government, or higher education; such non-profit institutes and organizations are included with the respective sectors whose interests they mainly serve.

(17) **Ibid.**, p. 47.

Statistical units in this sector are classified into the following six major S&T fields:

- natural sciences;
- engineering and technology;
- medical sciences;
- agricultural sciences;
- social sciences;
- humanities.

These six major fields are suggested in the UNESCO **Recommendation Concerning the International Standardization of Statistics on Science and Technology** referred to earlier in this paper. Table B presents details of the constituent sciences.

Other institutional sub-classifications, as suggested by the OECD, are for those countries with a large PNP sector. In these situations the OECD recommends distinguishing the resources of three types of units:

- government-linked units;
- independent PNP units;
- individuals or households.

Government

The OECD definition of this sector is:

"All departments, offices and other bodies which furnish but normally do not sell to the community those common services which cannot otherwise be conveniently and economically provided and administer the state and the economic and social policy of the community."(18)

The SNA definition of producers of government services includes all bodies, departments and establishments of government - central, state or provincial, district or county, municipal, town or village - which engage in a wide-range of activities. These activities include, for example, defence and law enforcement; health, cultural, recreational and other social services; promotion of economic growth and welfare and technological development. Also included in the SNA definition are the legislature and executive, regardless of how they are treated or accounted for in actual government accounts of budgets.

Public enterprises such as Petro-Canada and Ontario Hydro are excluded from this sector and included in the Business enterprise sector. Many non-profit organizations and bodies, however, are included in this sector if they either serve or are controlled by government, or both.

For international comparisons, there are no standard sub-sectors for government since there is no administrative structure sufficiently

(18) **Ibid.**, p. 46.

TABLE B. Fields of Science and Technology (UNESCO)

Fields of science and technology	Component sciences
Natural sciences	Astronomy, bacteriology, biochemistry, biology, botany, chemistry, computer sciences, entomology, geology, geophysics, mathematics, meteorology, mineralogy, physical geography, physics, zoology, other allied subjects.
Engineering and technology	Engineering proper, such as chemical, civil, electrical and mechanical engineering, and specialized subdivisions of these: forest products; applied sciences such as geodesy, industrial chemistry, etc.; architecture; the science and technology of food production; specialized technologies or interdisciplinary fields, e.g., systems analysis, metallurgy, mining, textile technology, other allied subjects.
Medical sciences	Anatomy, dentistry, medicine, nursing, obstetrics, optometry, osteopathy, pharmacy, physiotherapy, public health, other allied subjects.
Agricultural sciences	Agronomy, animal husbandry, fisheries, forestry, horticulture, veterinary medicine, other allied subjects.
Social sciences	Anthropology (social and cultural) and ethnology, demography, economics, education and training, geography (human, economic and social), law, linguistics, management, political sciences, psychology, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary, methodological and historical S&T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences.
Humanities	Arts (history of the arts and art criticism, excluding artistic "research" of any kind), languages (ancient and modern languages and literature), philosophy (including the history of science and technology), prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, etc., religion, other fields and subjects pertaining to the humanities and interdisciplinary, methodological, historical and other S&T activities relating to the subjects in this group.

Source: Frascati Manual, OECD, Paris, 1981, p. 49.

common to all countries. For national purposes, however, there are three recommended categories according to the level of government:

- central and federal units;
- provincial and state units;
- local and municipal units.

These sub-sectors are designed mainly to reveal differences between countries in the structure of their political systems. Thus, using this breakdown of the units, the OECD can rearrange the R&D data, so that international comparisons are more consistent.

For the same reason, it is recommended that countries identify organizations at the borderline between government and other sectors; for example, a unit that is administered or controlled by government but situated at, or associated with, the Higher education sector. By identifying them separately when reporting to an international organization such as the OECD, they can be assigned to the sector that best represents the institutional arrangements of all OECD countries.

Higher Education

According to the OECD this sector is composed of: "All universities, colleges of technology and other institutes of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating **under the direct control of** or **administered by** or **associated with** higher education establishments."(19)

By contrast, the United Nations SNA, normally includes higher education in the government sector. The OECD has created a separate sector, however, because of the important role universities and similar institutions play in the performance of R&D.

(19) **Ibid.**, p. 50.

The units of higher education are classified into the same major fields of science and technology as the PNP sector:

- natural sciences;
- engineering and technology;
- medical sciences;
- agricultural sciences;
- social sciences;
- humanities.

In this sector, R&D inputs are estimated by the statistical agency as in Education and Training which defined some R&D activity in universities by the proportion of working time devoted to R&D. It is therefore necessary to have supplementary criteria to enable the OECD to keep international comparisons consistent. These other institutional sub-classifications can be broken down into four types of units:

- teaching units;
- research units;
- medical units;
- testing units and other (e.g., agricultural experiment stations).

Abroad

This sector consists of: "All institutions and individuals located outside the political frontiers of a country except for vehicles, ships, aircraft and space satellites operated by domestic organisations and testing grounds acquired by such organisations."(20)

This sector also includes international organizations whose facilities and operations are situated inside the borders of a country. Foreign-owned subsidiaries are not included in this sector (e.g., Ford Canada is, for the purposes of measuring R&D expenditures, a domestic organization in the Canadian Business enterprise sector, even though its parent company is the Ford Motor Company of the United States).

The Abroad sector is included in the GERD only as a funding sector (see matrix), since by definition the GERD "...includes R&D performed within a country and **funded from abroad** but excludes payments made abroad for R&D".(21) Thus, funding from the Abroad sector is implicitly included in the intramural expenditures of the four performing sectors.

(20) **Ibid.**, p. 51.
(21) **Ibid.**, p. 80.

Chapter 4

GERD IN CANADA

Introduction

Having established a framework for describing R&D expenditures and in particular, GERD, a Canadian perspective is now presented. To examine how R&D input data are collected a general description of the survey methods for each sector is provided. As well, tabular displays are presented as examples. To begin, a brief history of the surveying authority responsible for the construction of the GERD statistical series is given.

Statistics Canada began collecting statistics on R&D expenditures in 1956. The aim was to provide the National Research Council with statistics to compare with a series released by the National Science Foundation of the United States. The first survey was of R&D in Canadian industry in 1955.

Over the years, surveys were started for other sectors and estimates were prepared for unsurveyed areas. The Canadian GERD series now begins in 1963. However, statistics on R&D in the social sciences and humanities fields were not included in the published estimates until eight years later, after a successful pilot survey of the federal government was conducted. In 1971, the federal government established the Ministry of State for Science and Technology (MOSST) which became the primary user of science statistics. In 1976, a satellite of Statistics Canada, the Science Statistics Centre, was co-located with MOSST to ensure closer co-operation between the producers and users of S&T indicators. In 1983, MOSST was re-organized and the arrangement was ended. The Science Statistics Centre received increased responsibilities and became the present Science and Technology Statistics Division (STSD).

The most important function of the STSD is to gather comprehensive data on the resources devoted to science and technology in Canada. The GERD is the central statistical series now produced by the STSD, and is published in the annual report, **Canadian Science Indicators** and in a spring release of the monthly service bulletin, **Science Statistics.**

The STSD is directly responsible for ensuring that all the reporting units observe the guidelines for measuring R&D expenditures. For the most part, the Canadian GERD is compatible with OECD classifications; but differences do exist. The treatment of the Social Sciences and Humanities field provide an example.

The OECD considers both the Natural Sciences and Engineering (NSE) and the Social Sciences and Humanities (SSH) when measuring R&D whereas, in Canada, usually only the NSE are considered. There are two principal reasons for this:

- The federal government has a policy of raising the national expenditures on R&D in the NSE to a level where GERD/GDP will equal 1.5% by 1985. This policy, and its summary equation, are widely quoted and discussed. The publication of another GERD series 10% greater than the one now known would cause confusion in spite of all qualifications and explanations that might accompany the original release of the statistics.

- Like most OECD members, no estimates have been made for SSH R&D in the Business enterprise sector. To date such a survey has not been considered feasible, although the topic is under investigation. By adding the SSH activities, the GERD structure, as now known in Canada, would be altered, resulting in additional weight being given to the estimates with the greatest possibility of error, i.e., those of the Higher education sector.

Thus, while there is a Canadian GERD estimate for SSH, it is not normally included in the GERD series. The OECD version of the Canadian GERD is presented both as NSE and SSH together and as NSE alone. Tables 1 and 2 which follow, show the Canadian GERD in the Natural Sciences and Engineering, and Social Sciences and Humanities (respectively) by performing and funding sectors for the year 1981.

As Table 2 illustrates, in 1981, total R&D expenditures in the SSH were $380 million. Of this total, the Higher education sector performed more than 80%. These figures are fairly typical of many OECD countries, in that universities perform the bulk of such R&D. However, other countries usually show government as the main funder of R&D (SSH) in the Higher education sector. In Canada, payments by governments made to the universities for general operating and capital costs are considered university funds when used to cover the costs of unsponsored research.

Another conclusion that can be drawn from Table 2 concerns the contribution that R&D in the SSH makes to the GERD (NSE + SSH). Compar-

ing Tables 1 and 2 it is apparent that SSH accounts for only about 9%(22) of total R&D expenditures in 1981. This proportion is relatively consistent since the first GERD (SSH) for 1971. By reviewing the GERD estimates for other OECD countries, it can be seen that Canada's emphasis on R&D in the NSE is fairly representative of the OECD area.

(22) This percentage is simply calculated by dividing the total in Table 2 by the combined total of Tables 1 and 2.

TABLE 1. GERD (NSE), 1981

Funding sector	Performing sector							Total
	Governments				Business enterprise	Higher education	Private non-profit	
	Federal	Provincial	Provincial research organizations	Total				
	millions of dollars							
Governments:								
Federal	865	–	1	866	179	322	1	1,368
Provincial	–	85	34	119	37	94	8	258
Provincial research organizations	–	–	5	5	–	–	–	5
Total	**865**	**85**	**40**	**990**	**216**	**416**	**9**	**1,631**
Business enterprise	–	–	11	11	1,652	3	1	1,667
Higher education	–	–	–	–	–	344	–	344
Private non-profit	–	–	–	–	–	56	20	76
Foreign	–	–	1	1	136	9	–	146
TOTAL	**865**	**85**	**52**	**1,002**	**2,004**	**828**	**30**	**3,864**

Source: "R&D Expenditures in Canada, 1963-1983", Statistics Canada, May 1983, p. 30.

TABLE 2. GERD (SSH), 1981

Funding sector	Performing sector					Total
	Governments			Higher education	Private non-profit	
	Federal	Provincial	Total			
	millions of dollars					
Governments:						
Federal	48	–	48	32	1	81
Provincial	–	21	21	26	–	47
Total	**48**	**21**	**69**	**58**	**1**	**128**
Higher education	–	–	–	249	–	249
Private non-profit	–	–	–	3	–	3
TOTAL	**48**	**21**	**69**	**310**	**1**	**380**

Source: "R&D Expenditures in Canada, 1963-1983", Statistics Canada, May 1983, p. 47.

The Sectors

Business Enterprise

This sector is defined as all firms, organizations and institutions whose primary activity is the production of goods or services for sale to the general public at a price intended approximately to cover at least the cost of production as well as non-profit institutes mainly serving such firms. Included - in accordance with the OECD guidelines given earlier - are those government owned enterprises such as Petro-Canada, the CNR and Canadian power utilities.

This is the only sector in which data are not collected on R&D in the social sciences and humanities.

Before 1969, data on industrial R&D expenditures were collected biennially. Since then, all known performers of industrial R&D have been surveyed for odd-numbered years and a sample, including the leading performers, has

TABLE 3. Total R&D Expenditures in the Business Enterprise Sector by Industry, 1978-82

Industry	1978	1979	1980	1981	1982
	millions of dollars				
Mines and wells					
Mines	18	21	31	46	49
Gas and oil wells	38	97	110	159	322
Total mines and wells	**56**	**118**	**141**	**205**	**371**
Manufacturing					
Food, beverages and tobacco	32	35	45	53	84
Rubber and plastic products	11	14	16	17	21
Textiles	5	7	9	9	10
Wood based industries	36	53	65	80	76
Primary metals (ferrous)	16	19	21	23	25
Primary metals (non-ferrous)	50	60	85	74	75
Metal fabricating	12	15	19	23	29
Business machines	18	27	43	55	79
Other machinery	43	55	68	73	81
Aircraft and parts	131	153	169	247	247
Other transportation equipment	22	33	39	49	56
Communications equipment	168	210	257	365	536
Other electrical products	44	60	75	86	100
Non-metallic mineral products	6	7	9	11	15
Petroleum products	98	116	132	208	269
Drugs and medicines	32	39	49	51	62
Other chemical products	54	66	88	102	114
Scientific and professional equipment	9	10	14	18	24
Other manufacturing industries	4	5	11	10	12
Total manufacturing	**791**	**984**	**1,213**	**1,556**	**1,915**
Services					
Transportation and other utilities	42	41	48	61	67
Electrical power	56	69	76	92	123
Engineering and scientific services	49	43	60	57	63
Other non-manufacturing industries	13	14	26	34	33
Total services	**160**	**168**	**210**	**243**	**286**
TOTAL, ALL INDUSTRIES	**1,007**	**1,269**	**1,564**	**2,004**	**2,572**

Source: "Standard Industrial R&D Tables, 1963-1983", Statistics Canada, March 1983, p. 26.

been surveyed for even-numbered years. From 1982 on, however, all known performers are surveyed annually.

The larger performers and funders receive questionnaires covering four years, while questionnaires for firms with smaller programs cover only one year of data. In 1982, for example, the "base year" was 1981. All firms responded to the 1981 fiscal year; in addition larger spenders were asked for data on R&D expenditures for 1980, 1982 and 1983.

Included in the survey are the two primary industries, mines, and gas and oil wells, all industries in the manufacturing sector, and some in the service sector (e.g., public utilities, engineering and scientific services). Industries not covered are agriculture, forestry, fishing and trapping, trade, finance, insurance, real estate, the community, most of business, and all of the personal services industries; the activities of these industries seem to involve little or no R&D.

The current industrial classification (1983) is illustrated by Table 3.

Aside from the obvious value of the yearly trends provided by Table 3 it also indicates the industries which perform the most R&D. For instance, in 1981 the biggest performers of R&D were those firms whose primary economic activity was the manufacture of communications equipment. Of the $2.0 billion in R&D expenditures, that industry was responsible for close to one fifth of total expenditures. The second biggest performer in 1981 were companies whose primary economic activity was the manufacture of aircraft and parts.

It is also useful to look at the source of funds for the performing industries in the Business enterprise sector. Table 4 provides a matrix of performing industries and funding sectors. It also illustrates how industries may be combined.

The table shows how much R&D industries performed and the source of funding. For instance, in the first row, mining and primary metal industries funded most of their own R&D in 1981. Only $15 million of the total $143 million came from outside the performing units. Government funded $4 million, other Canadian (mainly related companies) provided $3 million, and $8 million came from foreign sources.

TABLE 4. Sources of Funds for R&D in the Business Enterprise Sector, 1981

Industry	Performing company	Governments	Other Canadian	Foreign	Total
	millions of dollars				
Mines and primary metals	128	4	3	8	143
Gas and oil wells, petroleum products	271	22	42	31	367
Food, beverages and tobacco	46	4	2	-	53
Wood based industries	45	11	22	2	80
Business machines	20	4	1	31	55
Other machinery	63	7	-	2	73
Aircraft and parts	185	50	-	12	247
Other transportation equipment	44	4	-	-	49
Communications equipment	251	42	48	25	365
Other electrical products	71	10	1	4	86
Drugs and medicines	41	4	-	8	51
Other chemical products	91	8	2	1	102
Other manufacturing industries	71	12	4	4	90
Electrical power utilities	84	3	4	1	92
Other non-manufacturing industries	92	31	21	7	151
Total	**1,503**	**216**	**150**	**136**	**2,004**

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 26.

Most R&D performed within the Business enterprise sector is financed by the firms doing the work. For example, **direct** Government funding (that is, funding as reported by the Business enterprise sector) in 1981 amounted to just 11% of the total. However, **indirect** Government funding, such as the federal government's investment tax credit and special research allowance programs, is not included in Table 4. The cost of these programs to the federal government in foregone tax revenues or the tax payments saved by firms amounted to about $100 million in 1981.

Private Non-profit Organizations

The basic definition of the Private non-profit organization (PNP) sector is the same as the OECD definition and consists of private and semi-private organizations which do not have as their primary aim - to make a profit.

This is the smallest of the sectors in the Canadian GERD. It **exists mainly as a source of funds for medical research in the Higher education sector,** although there are some research institutes included in this sector.

As for the Business enterprise sector, the survey of this sector is done by a mail-out/mail-back questionnaire. The mailing list is made up from lists of previous respondents, from directories of associations, and from lists of donors of funds for R&D in the universities.

In Table 5, the trend from 1978 to 1982 for R&D (NSE) performed in this sector by funder is shown.

As a trend, the amounts funded to this sector have grown considerably during the last few years. By far the biggest source of funds for the PNP sector is itself (i.e., fees, dues and donations from members and sponsors). Table 5 does not show, however, the funding that the PNP sector provided to the Higher education sector, an amount almost double the expenditures on R&D performed by the PNP sector itself. Table 6 illustrates this point for the year 1980.

TABLE 5. Source of Funds for R&D Carried Out in the Private Non-profit Sector, 1978-82

Source	1978	1979	1980	1981	1982P
	millions of dollars				
Federal government	1	1	1	1	1
Provincial governments	6	6	7	8	9
Business enterprise	..	..	1	1	1
Private non-profit	12	14	15	20	24
Total	**19**	**21**	**24**	**30**	**35**

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 29.

TABLE 6. R&D Performed and Funded by the Private Non-profit Sector, 1980

Organization	Performed in the private non-profit sector	Funds for the higher education sector	Total
	millions of dollars		
Private philanthropic foundations	-	4	4
Voluntary health organizations	6	38	44
Societies and associations	1	--	1
Research institutes	17	--	17
Total	**24**	**42**	**66**

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 29.

Government

Within the Government sector three sub-sectors are distinguished for the Canadian GERD: the federal government, provincial governments and provincial research organizations.

Federal Government

This sub-sector includes all departments and agencies which are funded through parliamentary votes. In 1982, this involved a total of 111 departments, departmental programs and agencies. (For a detailed listing, see Appendix III.)

The federal government is surveyed by means of a mail-out/mail-back questionnaire called "Main Estimates Science Addendum" (MESA). It is called an addendum because it is completed as part of the submission of the main estimates of a department or agency of the Government of Canada to the Treasury Board. Responsibility for the conduct of this survey rested with the Ministry of State for Science and Technology which with Statistics Canada, provided guidance to the respective financial officers who responded to the questionnaire to make sure the appropriate data were included.

When the MESA are completed and returned, they are checked for completeness and correctness of computations and comparisons are made with previous years' data. They are continuously compared to the changing Main Estimates until the process is terminated by the Treasury Board.

The level of **intramural** R&D expenditures shown in MOSST reports is lower than that used for the GERD. MOSST requires the information for comparison with the Main Estimates, and expenditures conform to those allocated by budgetary program. However, this understates the cost of activities because of the omission of some services such as accommodation provided by Public Works or of those provided by departmental administration programs. Consequently, the Centre estimated such costs and added them to each scientific program. Table 7 shows intramural R&D (NSE) expenditures as reported by MOSST, and then the adjusted version by the Centre. The latter aggregation is the one used in the GERD series.

TABLE 7. Intramural R&D Expenditures (NSE), by Reporting Agency, 1980-81 to 1982-83

	1980-81	1981-82	1982-83
	millions of dollars		
Ministry of State for Science and Technology			
Agriculture	134	149	174
National Research Council	126	153	195
Energy, Mines and Resources	73	92	119
Environment	67	78	96
National Defence	71	73	81
Fisheries and Oceans	50	55	53
Other	144	171	195
Total	**665**	**771**	**913**
Statistics Canada			
Agriculture	153	171	200
National Research Council	129	157	200
Energy, Mines and Resources	82	105	133
Environment	77	88	108
National Defence	72	74	82
Fisheries and Oceans	52	57	55
Other	149	177	201
Total	**714**	**829**	**979**

Source: "Survey Methodology of the 1981 GERD", Science and Technology Statistics Division, p. 3.

On the other hand, the MOSST reports will show a higher level of **extramural** expenditures. The federal government, as a funder, often reports higher R&D payments to others than are identified by the performers. The GERD, of course, is made up from the performers' reports. This difference is shown in Table 8.

TABLE 8. Federal R&D Extramural Expenditures (NSE), by Reporting Method, 1980-81 to 1982-83

	1980-81	1981-82	1982-83
	millions of dollars		
Main Estimates Science Addendum			
Business enterprise	215	282	365
Higher education	254	313	352
Other	45	53	35
Total	**514**	**648**	**752**
GERD			
Business enterprise	119	179	229
Higher education	261	322	353
Other	4	2	2
Total	**384**	**503**	**584**

Source: "Federal Government Expenditures on Activities in the Natural Sciences, 1963-64 to 1983-84", Statistics Canada, May 1983. "R&D Expenditures in Canada, 1963-1983", Statistics Canada, May 1983.

In Table 9, the GERD for the federal government sector is shown for recent years. As was discussed in Chapter 3 (Government), the OECD has no established sub-sector classifications since there is no administrative structure sufficiently common to all countries. Hence, the breakdown by department in Table 9, while used for the Canadian GERD, is in no way representative of the OECD area. In the OECD version of the Canadian GERD, the departmental totals are added together for one figure, which can be then compared with the aggregated R&D expenditures of other government sectors.

TABLE 9. Expenditures on R&D Performed Within the Federal Government, by Department, 1978-82

Department	1978	1979	1980	1981	1982P
	millions of dollars				
Agriculture	126	143	153	178	199
Atomic Energy of Canada Ltd.	68	64	69	82	96
Energy, Mines and Resources	66	64	82	107	132
Environment	60	60	77	84	102
Fisheries and Oceans	67	67	75	85	92
National Defence	61	59	72	78	88
National Research Council	102	112	129	152	191
Other	86	77	80	99	116
Total	**636**	**646**	**737**	**865**	**1,016**

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 23.

Provincial Governments

This sub-sector represents all departments, ministries and agencies of provincial governments, including the Alberta Oil Sands Technology and Research Authority.

R&D expenditures of four provincial governments are surveyed annually by the Science and Technology Statistics Division. These surveys, of British Columbia, Alberta, Saskatchewan and Ontario, are carried out on behalf of provincial government sponsors (e.g., in Ontario for the Secretariat for Resources Development). Quebec recently instituted a survey of the scientific activities of the provincial government and the resulting statistics are used by the Division for the sub-sector estimates. The R&D expenditures of the five other provincial governments are estimated by the Division from

their respective Main Estimates and Public Accounts submissions to the appropriate legislative bodies.

The data collection process, from mailing out the questionnaires to edit and imputation, is similar to the process used for the MESA.

In Table 10, the trend from 1978 to 1982 for R&D (NSE) funded by this sub-sector is presented.

Provincial Research Organizations

All provinces, except for Newfoundland and Prince Edward Island, have a research council or foundation. These provincial research organizations (PRO) are surveyed annually by the Science and Technology Statistics Division. Data are collected on all activities of the organization: about 60% of total expenditures are for R&D and are included in the GERD.

These organizations are concerned primarily with R&D, as their titles indicate, and thus data collection is simpler and more direct than for most government departments where R&D is a relatively small percentage of program budgets.

Table 11 shows the 1981 expenditures of the PRO by activity.

TABLE 10. R&D Funded by the Provincial Governments, 1978-82

Year	Performing sector					Total
	Provincial		Business enterprise	Higher education	Private non-profit	
	Governments	Research organizations				
	millions of dollars					
1978	58	17	25	58	6	164
1979	65	21	27	60	6	179
1980	78	26	23	80	7	214
1981	85	34	37	94	8	258
1982	109	37	46	104	9	305

Source: "R&D Expenditures in Canada, 1963-1983", Statistics Canada, May 1983.

TABLE 11. Expenditures, by Scientific Activity, by Province, 1981

Provincial organization	Current						Capital	Total
	Scientific research	Develop-ment	Resource surveys	Analysis and testing	Industrial engineering	Other(1)		
	thousands of dollars							
Nova Scotia	569	1,442	379	379	266	760	233	4,028
New Brunswick	524	363	40	2,058	444	605	242	4,276
Québec	283	9,372	-	1,615	135	2,061	416	13,882
Ontario	3,763	6,843	-	5,474	171	855	3,438	20,544
Manitoba	229	687	-	458	344	574	575	2,867
Saskatchewan	2,157	1,177	2,844	1,863	392	1,373	505	10,311
Alberta	4,748	11,342	3,956	1,055	1,055	4,220	3,447	29,823
British Columbia	1,671	437	-	286	482	4,652	527	8,055
Total	**13,944**	**31,663**	**7,219**	**13,188**	**3,289**	**15,100**	**9,383**	**93,786**

(1) Feasibility studies $5,511; library and technical information $5,087; industrial innovation, $4,114; and other $388 thousand.

Source: Science Statistics, Vol. 6, No. 11, Statistics Canada, Catalogue 13-003, October 1982.

The Government Sub-sectors Combined

The three government sub-sectors are combined for the GERD estimate. In Table 12, performing and funding in each sector is displayed in a matrix of 1981 expenditures.

TABLE 12. Government Expenditures on R&D, 1981

Funding sector	Performing sector			Total
	Federal government	Provincial governments	Provincial research organizations	
	millions of dollars			
Federal government	865	-	1	866
Provincial governments	-	85	34	119
Provincial research organizations	-	-	5	5
Business enterprise	-	-	11	11
Foreign	-	-	1	1
Total	**865**	**85**	**52**	**1,002**

Source: Table 1.

Higher Education

This sector includes all universities, colleges of technology and other institutions of postsecondary education, whatever their source of finance or their legal status. Also included are all research institutes, experimental stations and clinics operating under the direct control of or administered by Higher education establishments.

R&D, in the sense of acquiring new knowledge, is an inherent part of higher education. It is very closely linked to the training of post-graduate students and is a function of most university teachers. In some institutes, staff and equipment are devoted exclusively to R&D.

Because of the close connection between R&D and instruction, it has not been possible to actually survey R&D activities in this sector. Estimates for the Higher education sector are generally derived from models based on an approximation of the amount of time spent by university staff on R&D. Data from a survey of university finances and expenditures by the Canadian Association of University Business Offices (CAUBO) are used to estimate the source of funds for R&D. (See Appendix IV for a detailed description of the survey methodology.)

Table 13 presents estimates of R&D performed in Canadian universities and the source of funds.

TABLE 13. Source of Funds for R&D Performed in Canadian Universities, 1978-82

Source	1978	1979	1980	1981	1982P
	millions of dollars				
Federal government	194	211	261	321	353
Provincial governments	53	60	80	94	104
Business enterprise	2	3	3	4	4
Higher education	301	329	347	344	376
Private non-profit	38	43	42	56	62
Foreign	6	7	8	9	9
Total	**594**	**653**	**741**	**828**	**908**

Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 29.

GERD by Region

In a country as large as Canada it is useful to have a general idea of where R&D activities are located, both to indicate the level of scientific and technical endeavour in a particular area and to use the statistics in association with other regional data.

For these reasons, the Canadian GERD has been broken down into geographical sub-sectors. For example, in Table 14, R&D expenditures in Canada are divided into four regions; the Atlantic provinces, Quebec, Ontario, and the Western provinces. The expenditures are assigned to the region in which the performing establishment is located. Personnel may live in an adjoining province (e.g., Ottawa-Hull) and materials and equipment will often come from another province or country; these data anomalies must be taken into consideration when using GERD as a regional indicator of S&T activity. The funding shown is of R&D carried out in a region; it is not R&D funding from a region.

Table 14 presents expenditures on R&D by performing regions and funding sectors for the year 1981.

TABLE 14. The Funding of Regional R&D, 1981

Funding sector	Atlantic provinces	Quebec	Ontario	Western provinces	Canada(1)
	millions of dollars				
Federal government	112	216	750	286	1,368
Provincial governments(2)	7	67	90	102	263
Business enterprise	16	365	890	393	1,667
Higher education(3)	41	130	126	121	420
Foreign	-	33	75	37	146
All sectors	**179**	**811**	**1,931**	**941**	**3,864**
	per cent of Canada total				
Federal government	8	16	55	21	100
	per cent of regional totals				
Federal government	63	27	39	30	35
Provincial governments(2)	4	8	5	11	7
Business enterprise	9	45	46	42	43
Higher education(3)	23	16	6	13	11
Foreign	-	4	4	4	4
All sectors	**100**	**100**	**100**	**100**	**100**

(1) Including the Yukon and Northwest Territories.
(2) Including provincial research councils and foundations.
(3) Including private non-profit institutions.
Source: Canadian Science Indicators, 1983, Statistics Canada, Catalogue 88-201, 1983, p. 18.

In the Atlantic region, the federal government is responsible for the largest share of R&D funding: in Quebec, Ontario and the Western provinces, the Business enterprise sector is the biggest funder of R&D representing approximately 50% of all R&D expenditures.

Chapter 5

A FINAL WORD: GERD AND INTERNATIONAL COMPARISONS

Overview

In the 1976 issue of **Science Indicators,** the U.S. National Science Board called attention to the many obstacles encountered in measuring and comparing the S&T efforts of individual countries: "International indicators of science and technology are faced with problems of data availability and reliability, and cross-country differences in definitions and concepts, methodologies, and statistical reporting procedures."(23)

Commenting in 1980 on the problem of finding reliable measures both of S&T activity and of research and development, the same publication stated: "Analysis of the status of U.S. science and technology represents a challenge because of the complexity of the enterprise itself, its multiple sources of support, its diverse performance settings, its relation to scientific and technological developments across the world, ...its multiplicity of purposes. Great interest exists for developing specific measures of the value and impact of science and technology, particularly of investment in research and development...".(24)

While the above comments were written in the context of U.S. scientific and technological effort, the issues are the same for the majority of industrialized and developing countries; that is finding reliable measures of S&T activity and, in particular, of research and development.

There are two major explanations. The first stems from the importance that most countries attach to knowing how much money is spent by other countries on R&D in order to assess their relative positions. The second is the illumination such comparisons throw on the national pattern.

GERD by Country

Direct international comparisons of the levels of effort devoted to R&D can be confounded by constantly fluctuating exchange rates among international currencies and changes in the relative costs of manpower and financial inputs into the R&D programs of different nations.

One of the methods the OECD employs to circumvent these difficulties is to express the GERD as a ratio of Gross Domestic Product (GDP).(25)

In absolute figures, U.S. R&D expenditures were 25 times those for Canada in 1979. In a GERD/GDP ratio, U.S. effort was slightly more than twice that in Canada. The latter provides a more relevant comparison because it takes into account the huge differences in size of population and economy.

The GERD/GDP ratio has become a standard OECD tool for international comparisons. For example, in Table 15 the trend over the last decade in the GERD in relation to domestic production changed little for most of the countries. Canada's highest ratio was at the start of the 1970's, and after falling between 1972 and 1977, began to rise as the decade came to a close. The pattern is similar for the other countries in Table 15, with the exception of Japan and Sweden. The ratios of these countries show substantial increases in R&D over the decade.

The GERD/GDP ratio is also a convenient summary statistic for government policy. For instance, the Canadian government has established a goal of a GERD/GNP ratio of 1.5% by 1985 (for NSE). While individual definitions are different, other governments have set similar goals, for example; both France and Japan have set targets of 2.5% for 1985, Finland is aiming for 1.6% and Greece has a goal of 1.2% by 1987.

For some comparisons the OECD classifies Member countries into four categories: major R&D countries, medium R&D countries, small R&D countries, and countries giving little or no priority to R&D. As such, Switzerland and Sweden are in the same group (see Table 16) as Canada, despite significant differences in their GERD/GDP ratios (see Table 15).

(23) **Science Indicators - 1976,** National Science Board, Washington D.C., U.S.A., 1977, p. 4.

(24) **Science Indicators - 1980,** National Science Board, Washington D.C., U.S.A., 1981, p. vii.

(25) The GDP is one of the standard economic indicators used by the OECD. In general terms it is a measure of the total value of production of goods and services of a country's residents within the boundaries of that country.

TABLE 15. **GERD and GDP of Selected OECD Countries, Selected Years, 1971-79**

Country	1971	1973	1975	1977	1979
	per cent GERD/GDP				
Canada	1.35	1.12	1.11	1.07	1.12
France	1.91	1.78	1.80	1.76	1.82
Germany	2.19	2.09	2.22	2.14	2.27
Japan	1.83	1.87	1.94	1.91	2.04
Netherlands	2.17	2.01	2.12	1.99	1.98
Sweden(1)	1.48	1.60	1.75	1.87	1.89
Switzerland	2.33	2.25	2.40	2.29	2.45
U.S.A.	2.68(2)	2.50	2.44	2.39	2.41

(1) Excludes expenditures on R&D in the social sciences and humanities.
(2) Estimate.
Source: Science Statistics, Vol. 6, No. 12, Statistics Canada, Catalogue 13-003, November 1982.

TABLE 16. **Total Resources Devoted to R&D in the OECD Area in 1979**

Country	GERD		Researchers		Total R&D personnel	
	Total	NSE	Total	NSE	Total	NSE
	millions of $ U.S.		thousands		thousands	
United States	56,560	..	621.0	603.3(1)	133.4(2)	..
Japan	18,285	16,191	367.0(3)	304.8(3)	605.5(3)	524.1(3)
Germany	12,531	11,977	122.0	110.7	363.2	344.5
France	7,964	..	72.9	..	230.8	..
United Kingdom - 1978	7,961(1)	7,715	104.4(1)	98.9(1)	310.0(2)	(2)
Italy	3,086	2,371	46.4	38.9	94.6	86.2
Canada	2,438	2,191	26.3	22.0	59.0	51.5
Netherlands	2,098	1,892	18.3	14.8	53.8	48.3
Sweden	1,608(1)	1,532	..	14.8	..	36.4
Switzerland	1,469	1,436	10.7	9.8	36.3	35.6
Australia	1,183	1,065	22.3	17.6	40.6	35.1
Belgium	1,074	1,022	10.9	9.2	32.1	30.1
Austria - 1975	345	296	5.4	4.2	15.4	13.3
Norway	524	457	7.1	5.6	14.7	12.6
Denmark	417	372	6.0	4.8	15.3	13.7
Yugoslavia	586	518	22.4(3)	17.7(3)	51.3(3)	43.7(3)
Finland	406	370	7.4	5.9	16.0	14.2
New Zealand	166	154	..	..	8.1	7.4
Ireland	116	105	2.6	2.0	6.2	5.3
Spain - 1976	521	498	..	..	..	..
Portugal - 1978	91	83	2.1	..	6.5	5.8
Greece	75	64	2.6	2.0	4.3	3.6
Iceland	14	13	0.3	0.3	0.6	0.5

(1) Partially an OECD estimate.
(2) Wholly an OECD estimate.
(3) Not in FTE.
Source: OECD SCIENCE AND TECHNOLOGY INDICATORS 1, Trends in Science and Technology in the OECD Area, During the 1970s: Resources Devoted to R&D, OECD, DSTI/SPR/81.27, Paris, 1982, p. 16.

These three countries (Switzerland, Sweden, and Canada) along with Italy, Belgium, Australia and the Netherlands, are the medium R&D countries. "These seven countries are geographically dispersed and do not share membership of any specific economic or political group. They have been considered together purely because of the size of their national R&D efforts. What they do have in common is that they all spend significantly less on R&D than the five (major R&D) countries and significantly more than the smaller and far less industrialized countries...".(26)

In other words, their GERD's are closer in size than either the major or small R&D countries. In looking at the OECD area as a whole this division is practical in the same way that the GERD as a ratio of the GDP is convenient; not for the purposes of comparison, but rather to establish a framework from which the multitude of variables (inherent when dealing with more than 20 countries of different needs and priorities) can be examined more closely.

(26) **OECD SCIENCE AND TECHNOLOGY INDICATORS 1, Trends in Science and Technology in the OECD Area, During the 1970s: Resources Devoted to R&D,** OECD, DSTI/SPR/81.27, Paris, 1982, p. 149.

BIBLIOGRAPHY

Canadian Government Publications

Statistics Canada, "Program Evaluation: Science Statistics Program" (Ottawa, Statistics Canada, September 1982).

Statistics Canada, Ministry of State for Science and Technology "R&D Expenditures in Canada, 1963-1983" (Ottawa, Statistics Canada, May 1983).

Statistics Canada, Ministry of State for Science and Technology "Standard Industrial R&D Tables, 1963-1983" (Ottawa, Statistics Canada, June 1983).

Statistics Canada, **Canadian Science Indicators, 1983,** Catalogue 88-201 (Ottawa, Statistics Canada, 1983).

Statistics Canada, **Annual Review of Science Statistics, 1982,** Catalogue 13-212 (Ottawa, Statistics Canada, 1982).

Other Publications

OECD, **The Measurement of Scientific and Technical Activities - Proposed Standard Practice for Surveys of Research and Experimental Development** (Paris, OECD, 1981).

OECD, **OECD SCIENCE AND TECHNOLOGY INDICATORS 1, Trends in Science and Technology in the OECD Area During the 1970s: Resources Devoted to R&D,** DSTI/SPR/81.27 (Paris, OECD, September 1982).

UNESCO, **Guide to the collection of statistics on science and technology** (Paris, UNESCO, July 1977).

National Science Board, **Science Indicators - 1976** (Washington D.C., United States, National Science Board, 1977).

National Science Board, **Science Indicators - 1980** (Washington D.C., United States, National Science Board, 1981).

Appendix I

UNESCO AND THE OECD

United Nations Educational, Scientific and Cultural Organization (UNESCO)

The UNESCO Division of Statistics on Science and Technology has organized the systematic collection, analysis, publication and standardization of data concerning science and technology since 1965. Its data base at present covers some 80 countries and is primarily concerned with human and financial inputs to R&D. Even though the data compiled are not perfectly homogeneous, there are an increasing number of requests for their use by national and international organizations, particularly by officials responsible for the formulation and planning of science policies.

UNESCO achievements in the development of measuring scientific and technical activity are marked by the following publications:

Provisional Guide to the Collection of Science Statistics (1968);

Manual for Surveying National Scientific and Technological Potential (1969);

Guide to the Collection of Statistics on Science and Technology (1977); and

Recommendation Concerning the International Standardization of Statistics on Science and Technology (1978).

The last publication listed was developed in response to an expressed need for international standards that could be applied to all member states, both those having advanced systems in the field of science statistics (e.g., United States, Japan, Germany and Canada), and those where these statistics are still in development (e.g., India, Saudi Arabia, Nigeria and Mexico). This Recommendation provides international guidelines for member states in the hope that ultimately it will lead to an improvement in the quality and comparability of international science statistics.

Organisation for Economic Co-operation and Development (OECD)

The OECD counterpart to the UNESCO guide is: **The Measurement of Scientific and Technical Activities - Proposed Standard Practice for Surveys of Research and Experimental Development** or, the "Frascati Manual". Much of the present paper is a summary, or rather, a simplification of the Frascati Manual since it fits within UNESCO recommendations on all S&T activity but is specific to R&D and to the needs of OECD member countries, which have rather similar economic and scientific systems which distinguish them from non-OECD countries. The 24 OECD members include most countries of Western Europe, the United Kingdom and Ireland, Scandinavia and Iceland, Australia, New Zealand, Japan, the United States and Canada. Most OECD countries have been collecting statistical data in the S&T field since the 1960's. Differences in scope, methods and concepts, have made international comparisons difficult and countries have encountered theoretical problems when starting R&D surveys. The Frascati Manual is the result of the OECD recognizing and examining this increasing need for standardization. It addresses the problem of surveying techniques and provides a rigorous conceptual separation of R&D and other activities with a scientific and technological base.

Appendix II

PERSONNEL AS A MEASURE OF R&D

Like extramural expenditures on R&D, personnel is considered a supplementary measurement to the basic measure, intramural expenditures on R&D. However, the Frascati Manual states: "Personnel is a more concrete measure and, since labour costs normally account for 50%-70% of total R&D expenditures, is also a reasonable short-term indicator of efforts devoted to R&D. The measurement of the personnel engaged in R&D is also of fundamental importance in the longer term. Unless people with certain training and qualifications are available, organised R&D is almost impossible. Education and training are lengthy processes; personnel data are, therefore, essential to realistic science policy planning."(27)

It is essential to classify R&D personnel into categories because of the wide variety of persons needed and the range of skills and education required. There are two systems in practice; classification by occupation and classification by level of formal qualification. The classification by occupation is broken down into three levels of personnel; researchers, technicians and equivalent staff, and other supporting staff. The formal qualification categories are university graduates, holders of other postsecondary diplomas, and high-school graduates. (They correspond respectively to ISCED(28) level categories 6 and 7, 5 and 3.) Both systems are used by OECD Member countries. Canada uses the first system; classification by occupation is presented here.

Researchers are scientists or engineers engaged in the conception or creation of new knowledge, products, processes, methods and systems. This level also includes managers and administrators engaged in the planning and management of the scientific and technical aspects of a researcher's work. They are usually of equal rank to the researchers and are often former or part-time researchers themselves. Post-graduate students, in particular those students performing significant amounts of R&D, are included in this category.

Technicians and equivalent staff participate in R&D projects by performing tasks normally under the supervision of scientists and engineers or researchers in the social sciences and humanities. These tasks might include, for example, preparing computer programs, carrying out tests and experiments or statistical surveys and interviews.

Other supporting staff include skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects. Under this heading are also those managers and administrators concerned mainly with financial/personnel matters of a direct service to R&D projects.

Since not everybody involved in R&D is engaged exclusively in R&D, it is necessary to express their number on a full-time equivalent (FTE) basis or person-years. If only those persons employed in pure R&D establishments were counted, the result would be an underestimate; just as counting everybody who spends some time on R&D would result in an overestimate.

In summary, personnel, as a measurement of R&D input, is the FTE of all persons employed directly on R&D as well as those providing direct services such as R&D managers, administrators and clerical staff. Those providing an indirect service (e.g., canteen and security staff) should be excluded. Their wages and salaries, however, are included in R&D intramural expenditures.

(27) **Frascati Manual,** op. cit., p. 19.
(28) The International Standard Classification of Education is an established classification system of the United Nations.

TABLE C. Personnel Engaged in R&D by Occupational Classification (Suggested Relation Between OECD and ISCO(1) Classes)

OECD class	ISCO classes	ISCO number
Researchers	Chemists, physicists, physical scientists, n.e.c.	011, 012 and 013
	Biologists, medical scientists and related scientists, bacteriologists and related scientists, agronomists and related scientists	051, 052 and 053
	Statisticians, mathematicians and actuaries, systems analysts	081, 082 and 083
	Economists	090
	Lawyers, jurists, n.e.c.	121 and 129
	Sociologists, psychologists, anthropologists, geographers, historians and political scientists	192
	Librarians, archivists and curators	191
	Civil, electrical, mechanical, chemical, metallurgical, mining and industrial engineers, and engineers, n.e.c.	022-029 inclusive
	University and higher education teachers	131
	Administrators and managerial workers (part)	Major group 2
Technicians and equivalent staff	Physical and life science technicians	014 and 054
	Surveyors, draughtsmen, civil, electrical, mechanical, chemical, metallurgical, mining and other engineering technicians	031-039 inclusive
	Statistical and mathematical technicians, including computer programmers	084
	(Survey interviewers)	(none)
Other supporting staff	Agricultural, service and production and related workers	Major groups 6, 7, 8 and 9
	Clerical workers and related workers	Major group 3
	Administrators and managerial workers, n.e.c.	Major group 2

(1) International Standard Classification of Occupation.
Source: Frascati Manual, OECD, Paris, 1981, p. 68.

Appendix III

LIST OF FEDERAL GOVERNMENT DEPARTMENTS, PROGRAMS AND AGENCIES SURVEYED FOR R&D

Agriculture:
- Administration
- Canadian Grains Commission
- Food, Regulation and Inspection
- Food Development Program

Atomic Energy Control Board

Atomic Energy of Canada Ltd.

Canada Council

Canada Employment and Immigration Commission

Canada Mortgage and Housing Corporation

Canadian Arsenals Limited

Canadian Broadcasting Corporation

Canadian Dairy Commission

Canadian Human Rights Commission

Canadian International Development Agency

Canadian Livestock Feed Board

Canadian Radio Television Commission

Canadian Transport Commission

Canadian Unity Information Office

Commissioner of Official Languages

Communications:
- Arts and Culture

Consumer and Corporate Affairs:
- Administration
- Combines Investigation and Competition Policy
- Consumer
- Corporate

Economic Council of Canada

Employment and Immigration:
- Administration

Energy, Mines and Resources:
- Minerals and Earth Sciences
- Energy Program

Environment:
- Administration
- Environmental Services - Atmospheric Environment Service
- Environmental Services - Conservation Services
- Environmental Services - Environmental Protection Services
- Canadian Forestry Service
- Parks Canada

External Affairs:
- Canadian Interests Abroad

Finance:
- Financial and Economic Policies

Fisheries and Oceans:
- Fisheries and Marine Services

Indian and Northern Affairs:
- Indian and Inuit Affairs
- Northern Affairs

Industry, Trade and Commerce:
- Grains and Oilseeds
- Tourism
- Trade - Industrial

International Development Research Centre

International Joint Commission

Justice:
- Administration of Justice
- Law Reform Commission

Labour

Medical Research Council

Ministry of State for Economic Development

National Capital Commission

National Defence:
- Defence Service

National Energy Board

National Film Board

National Health and Welfare:
- Administration
- Health and Social Services
- Health Protection
- Income Security
- Medical Services

National Library

National Museums of Canada

National Research Council:
  Scientific and Industrial
  Scientific and Technical

National Revenue - Taxation

National Sciences and Engineering Research Council

Privy Council

Public Archives

Public Service Commission

Public Works:
  Professional and Technical

Regional Economic Expansion

Royal Canadian Mounted Police

Science and Technology (Ministry of State)

Science Council of Canada

Secretary of State:
  Administration
  Official Languages
  Citizenship
  Translation

Secretary of State for Social Development

Social Sciences and Humanities Research Council

Solicitor General:
  Administration

Statistics Canada

Supply and Services - Supply

Transport:
  Air Transportation
  Administration
  Marine Transportation
  Surface Transportation

Treasury Board (Central Administration)

Appendix IV

A DESCRIPTION OF THE HIGHER EDUCATION SECTOR SURVEY METHODOLOGY

The Science Statistics Centre employed the following procedures to derive statistics for the Higher education sector:

"1. Obtains the latest statistics on university finance and expenditures from the annual CAUBO survey and subtracts the costs of ancillary enterprises, scholarships and bursaries (as obviously not relevant to R&D).

"2. Obtains the latest statistics on full-time university teachers, arranging them into major disciplinary groups (fine and applied arts, social sciences, health sciences, and other natural sciences). These statistics, and those from the CAUBO survey, are provided by the Education, Culture and Tourism Division of Statistics Canada.

"3. Weights the numbers of teachers in each group in order to reflect the different requirements for services and facilities. The arts and social science groups are given a weight of 1, the health sciences a weight of 2.5, and the other natural sciences receive a weight of 2.

"4. The weighted numbers of university teachers are then used to form proportions for each year. For example, in 1979-80, the weighted arts proportion was 3.2%, social sciences was 34.8%, health sciences was 24.6% and the other natural sciences proportion was 37.4%.

"5. These proportions are applied to the selected university costs obtained earlier. Hence if total teaching and research costs were $3,470 million in 1979-80, costs attributable to the social sciences were $1,208 million.

"6. The calculation of the costs attributable to R&D are based on an estimate of the faculty time spent on R&D for each group. Ratios of 20% for the social sciences and 30% for the natural sciences were derived from information available in several Canadian and U.S. studies. These ratios are applied to the total teaching and research costs for each group of sciences. Thus, of the total expenditures on the social sciences of $1,208 million in 1979-80, $242 million is estimated to be the total cost of the R&D carried out within the Higher education sector.

"7. The sources of funds for the R&D must be calculated, although some are available from the CAUBO survey mentioned earlier. Federal government funds are those reported for each major science area in the MESA survey for the corresponding fiscal year. Funds from provincial governments are those of the CAUBO statistics, allocated to science areas from the proportions found for surveyed provincial governments. The very small funding from the Business enterprise sector is reported in the survey of that sector and allocated to the science fields based on the following approximations: 10% to the social sciences, 40% to the health sciences and 50% to the other natural sciences, including engineering. Funding by the Private non-profit organization sector is derived from the survey of these organizations. The identification of foreign funds are now obtained from the CAUBO survey. The difference between total costs of R&D and the total funds from other sectors is attributed to the Higher education sector. These are mainly costs which are not specially funded, either the indirect costs of sponsored research or the costs of research carried out without a grant or contract."(29)

It is noted that the method of estimating R&D expenditures in this sector is currently being reviewed for Statistics Canada.

(29) "Survey Methodology of the 1981 GERD", Science and Technology Statistics Division, pp. 12 and 13.

Appendix V

PROPOSED PUBLICATIONS ON SCIENCE AND TECHNOLOGY INDICATORS

Catalogue

88-501 An Indicator of Excellence in Canadian Science

88-502 Technology and the Balance of Payments

88-503 Technology and Commodity Trade

88-504 Patents as Indicators of Invention

88-505 Productivity, Science and Technology

88-507 An Indicator of Excellence in Canadian Science: Summary Report

88-508 Human Resources for Science and Technology in Canada

These publications will be available in French also.

Statistical reports describing activities in Canada with regards to each indicator series are being developed over the next year and are intended for annual publication by Statistics Canada.

STATISTICAL PUBLICATIONS

Catalogue

88-001 Science Statistics, monthly

88-201 Canadian Science Indicators, annual

88-202 Industrial Research and Development Statistics, annual

88-203 Resources for Research and Development in Canada, annual

88-204 Federal Science Activities, annual